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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

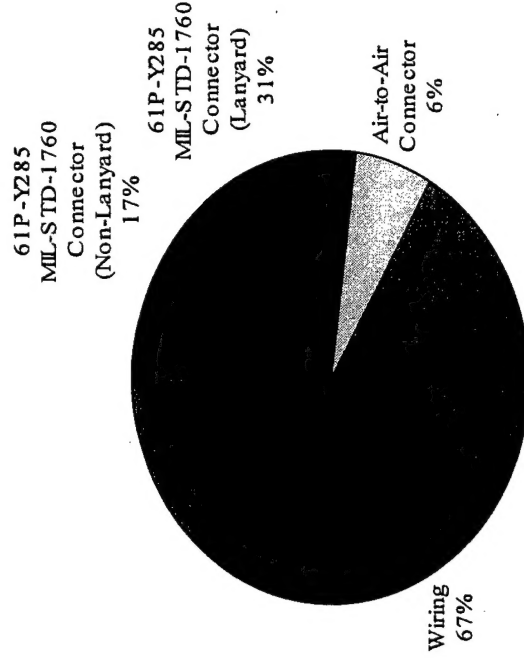
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Development and Testing of the F/A-18 Replacement MIL-STD-1760 Umbilical

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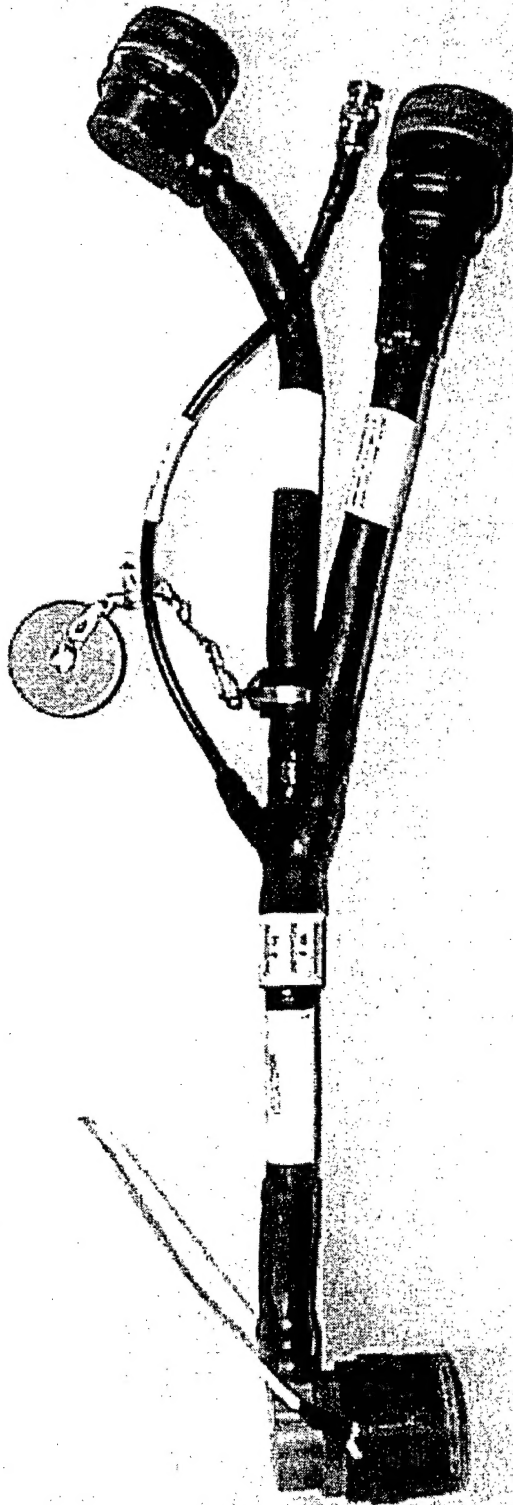
Background

- Existing umbilical designed for AWW-13
- Doesn't Fit well with existing weapons
- Umbilical failures during certification/integration testing
- Replacement cable required
 - modification not feasible



Development of Replacement

- Improved Performance
 - improved fit with current and future 1760 stores
 - improved service life (Reusable for 25~30 releases)
 - MIL-STD-1760 connector
 - control pull forces and prevent jamming, especially at high pull angles
 - improve impact resistance
 - Air to Air backshell improve impact resistance
 - Wiring
 - provide additional support at joints
 - spiral wires for strain relief and flexibility
 - Reduce bulk
 - Increase flexibility
- Repairable
 - Cost as an independent variable
 - New technology items



Qualification Program Goals

- Ensure cable would function properly
- Estimate a realistic service life to serve as a basis for procurement decisions
- Focus on issues related to failure modes of the existing cable and technological improvements in lanyard release connectors and low weight flexible cable.

Major Issues

- Use of composite connectors with Kevlar lanyard in open pylon area and severe wind and moisture environment
 - durability in F/A-18 flight effects
 - environmental effects
 - lightning effects
- High Pull Angle Lanyard Release Performance
- Wiring assembly durability with repeated installation/removal and in F/A-18 flight effects

Qualification Test Program

- Fit
- Electrical Compatibility
- E3 (EMC/EMI/EMV, HERO, Lightning)
- Environmental
- Static Pull
- Static Ejection
- Captive Carriage (Post-release configuration)
- Release Testing, not official part of qualification program but testing has subsequently been performed

Lightning Test Requirement

- The lightning threat scenario at issue:
 - A direct strike to the nose of the weapon, transmitted through the weapon to the aircraft via current paths (including the cable), traveling through the aircraft and exiting the tail of the aircraft.
 - Direct lightning strikes were not considered to be a threat for this cable due to the cable location within the pylon bay and weapon attachment point.
 - Concern was the ability of the composite components of the cable to withstand and remain functional when exposed to direct lightning effects as a major current path
 - Indirect lightning effects are considered less severe and answerable by the direct effects issue.

Lightning Zone and Test Parameters

- Determined to be Zone 3
 - Umbilical is a major current path for the lightning to traverse from the weapon to the aircraft
 - Other Major current paths (for a total of 5 paths):
 - Forward swaybrace and ejector foot units
 - Aft swaybrace and ejector foot units
 - Forward Lug/Hook Interface
 - Aft Lug/Hook Interface
 - To provide a conservative simplifying assumption, all current paths are assumed of equal impedance, but all paths applied.
- Waveforms for Zone 3 tests --“ABCD” of MIL-STD-464 Figure 1.
- The Umbilical is considered mission critical equipment and required to be tested to full threat levels.
 - Documented lightning strike history of F/A-18 shows required avionics for store release would typically be functional after a lightning strike
 - Cable should not be permitted to be the failing item.

Lightning Test Parameters

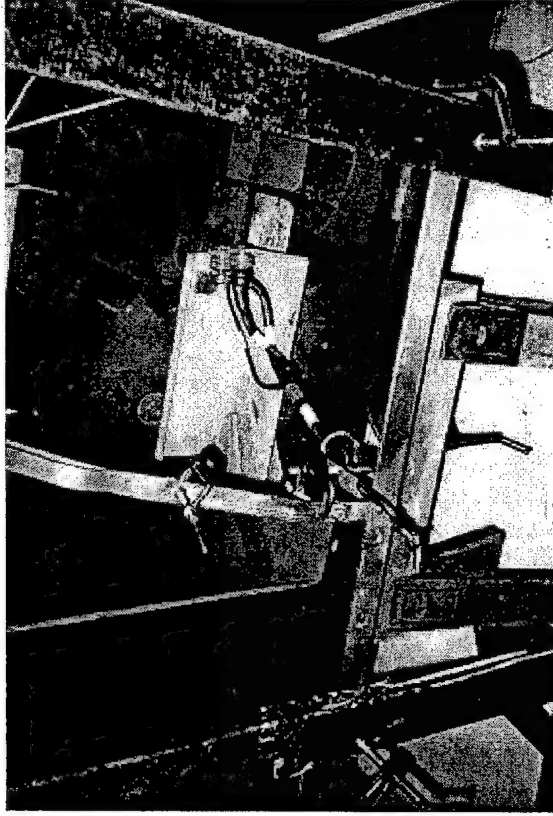
- The cable was required to be subjected to the following lightning indirect effects waveform parameters (MIL-STD-464 Figure 1 parameters, full threat level, divided by 5 equal current paths):

| Current Component | Description | Current Waveform Parameters | | | |
|-------------------|----------------------|--|---|--|--|
| | | Amplitude | Action Integral | Charge Transfer | Time |
| A | Initial Stroke | $200,000 \div 5 = 40,000$ A Peak $\pm 10\%$ | 2×10^6 A ² s $\pm 20\%$ | - | $< 500 \mu\text{sec}$ |
| B | Intermediate Current | $2000 \div 5 = 400$ A Avg $\pm 10\%$ | - | $10 \div 5 = 2$ Coulombs Max | $< 5 \text{ msec}$ |
| C | Continuing Current | $(200 \text{ to } 800) \div 5 = 40 \text{ to } 160$ A Avg $\pm 20\%$ | - | $200 \div 5 = 40$ Coulombs $\pm 20\%$ | $0.25 \text{ sec} < T < 1 \text{ sec}$ |
| D | Restrike | $100,000 \div 5 = 20,000$ A Peak $\pm 20\%$ | 0.25×10^6 A ² s $\pm 20\%$ | - | $< 500 \mu\text{sec}$ |

Pass/Fail Criteria

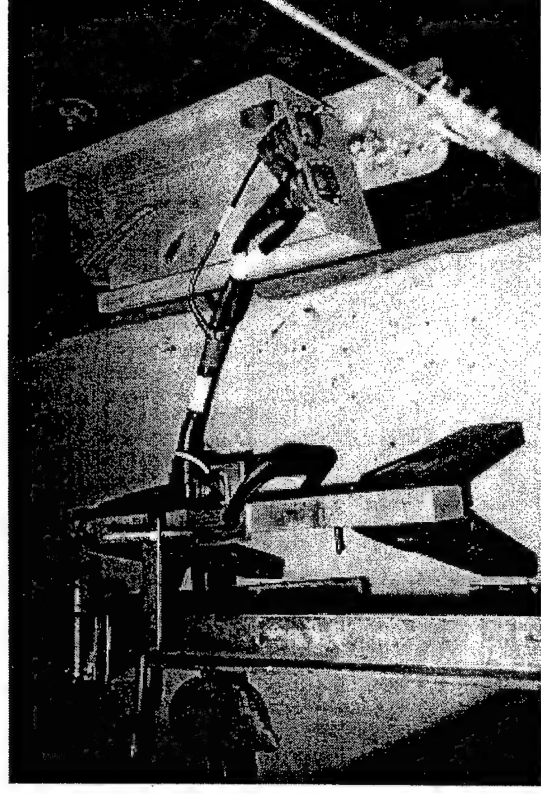
- Must remain physically and functionally intact to support continued carriage after the strike and employment or downloading of the weapon.
 - Due to the nature and low cost of the cable, reuse of the cable on subsequent missions is desired, but not required.
 - The Lanyard release connector must separate from the simulated weapon receptacle with reasonable pull force (hand pulled)
 - The A/A, A/G, and video connectors are desired, but not required, to be readily removed (not fused) from their mated receptacles.
 - Cable must retain continuity through signal paths, with no induced shorts.
 - Damage to shielding will be evaluated based on its impact to the ability to employ the weapon with degradation measured from pre-test baseline levels (test/cable tolerance assumed to be 5 dB).
 - Other damage will be evaluated on the basis of its impact to weapon employment.
 - If damaged, prefer visible indications.

Lightning Setup



Lightning applied
through rod to plate.

Umbilical installed in
fixture and attached to 4
in x 4 in x3/4 in plate
with receptacle.



Lightning Tests

- Whoops! On first event Waveform C failed to turn off. Conservative estimates of >300 Coulombs applied (vice 40 Coulombs +/- 20% test requirement)
- Other Test Events occurred normally
- Results- All Cable/Connectors showed satisfactory performance

Captive Carriage Tests

- Post-Release Configuration
- 1 Flight with specific maneuvers (add matrix and results)
- Additional flight to collect flight time (approx. 32 hrs)
- 4 Umbilicals
 - 2 completed 100 releases
 - 1 completed 58 releases
 - 1 new

Static Pull Tests

- 6 New MIL-C-38999/31 Connectors static pull tested
 - to assure the connector type complies with separation requirements
 - to obtain a pull force baseline for in specification pull angles and out of specification pull angles to support ejection test stand and future store separation tests.
- Each connector was pulled 10 times at 0, 5, 10, and 15 deg (within specification pull angles) and then as time permitted 16 deg to 25 deg (beyond specification pull angles).
- Receptacle replaced every 5 pulls
- Lanyard Orientation Varied
- Fixed Pull Rate of 1.6 in/sec
- Pull Force Measured
- Video

Ejection Tests

- Tests store separation from a test stand to assess umbilical service life performance.
 - 6 Prototype Umbilical Cables
 - 100 times each
- Locally developed variable CG Test store used for tests
 - CG changed from (15 to 30 in afl) to vary pull angle and rate
 - 2 Receptacle Positions (9 and 15 in aal)
- High Speed Video

DOD-C-38999/31

Durability:

No release force measurement required
Lanyard release velocity during pull-separation of
 $9.15\text{m/s} = 30.02\text{ ft/s} = 360\text{ in/s}$

Pull separation force:

400 N (90 lbf) max force for straight pull
445 N (100 lbf) max for for 15° pull
Pull rate not exceeding $13\text{ cm/s} = 0.426\text{ ft/s} = 5.12\text{ in/s}$

Our Tests:

Ejection test was between $6.25\text{ ft/s} = 75\text{ in/s}$ and
 $11.25\text{ ft/s} = 135\text{ in/s}$
Static test was at 1.6 in/s

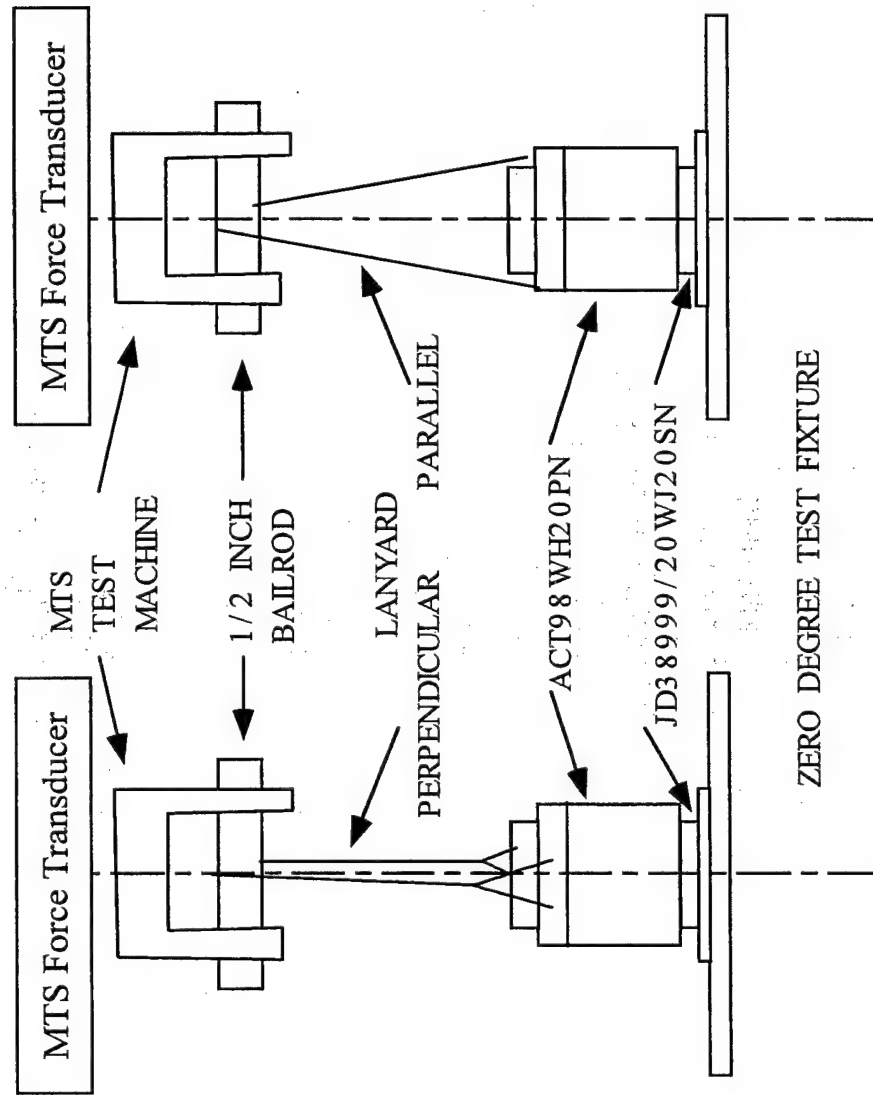
DOD-C-38999/31

“Durability: Wired connectors shall meet the durability requirements of MIL-C-38999, with the following exception:

The total number of cycles of mating and unmating shall be 500, in the following sequence: 200 cycles of normal mating and unmating, 50 cycles of normal mating with pull-separation unmating, 200 cycles of normal mating and unmating, and 50 cycles of normal mating with pull-separation unmating. The lanyard release velocity during the pull-separation unmating cycles shall be 9.15 m/s.

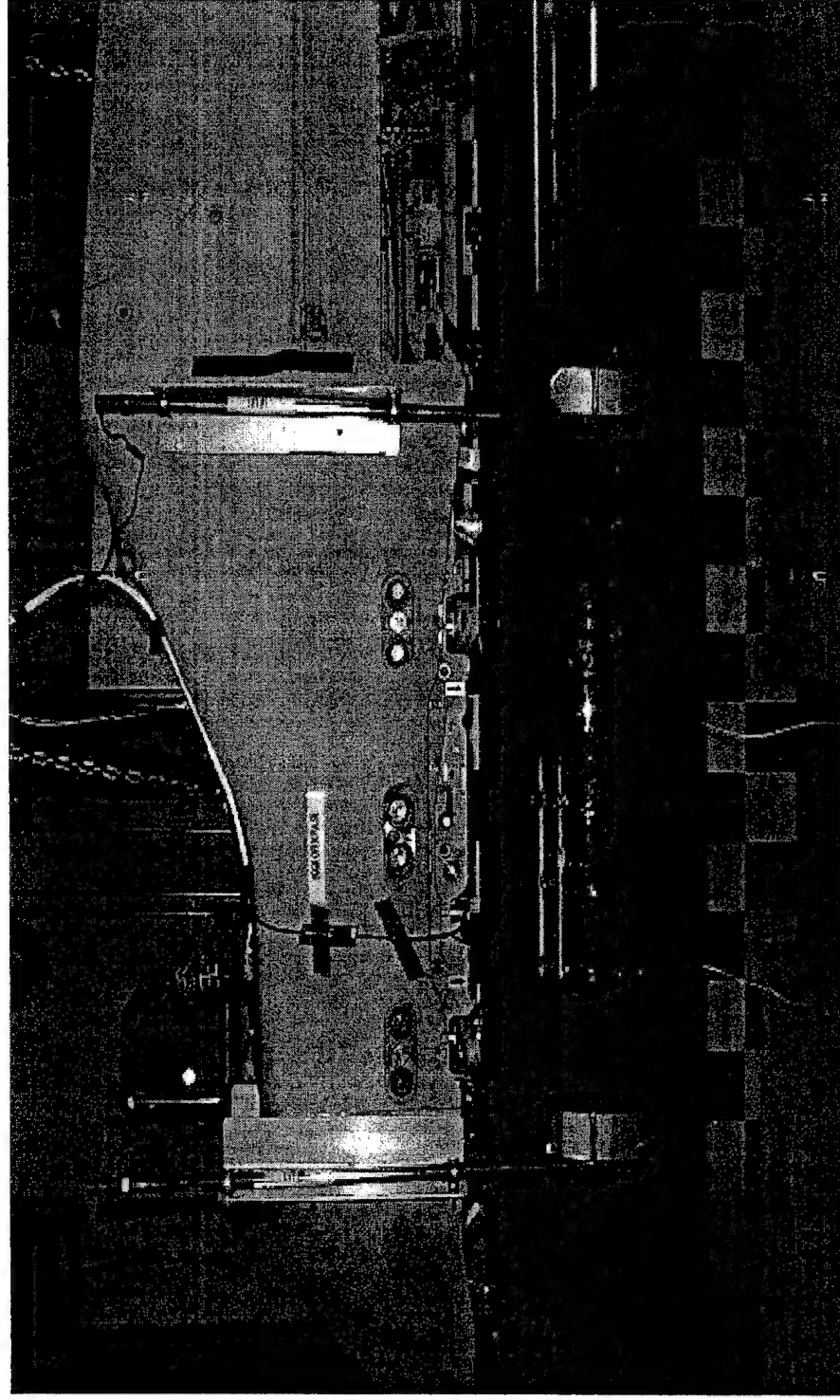
Pull-separation force: In addition to mating and unmating by normal coupling ring rotation, the connector shall be capable of lanyard-pull separation at any angle within 15 degrees of the normal axis. Each connector shall have one straight pull and one pull at 15 degrees from straight, with a pull rate not exceeding 13 cm/s. The test will be at -65°C, at ambient, and at the maximum temperature of the specified class. The test will be conducted within three minutes after removal from the temperature chamber without forced heating or cooling. Maximum separation forces shall be 400 newtons for a straight pull and 445 newtons for a 15 degree pull.”

Static Test Setup



COMPOSITE MIL-STD-1760 LANYARD CONNECTOR STATIC TEST SET-UP

Ejection Test Setup



3 L.V.T.'s

Cable Electric
Disconnect

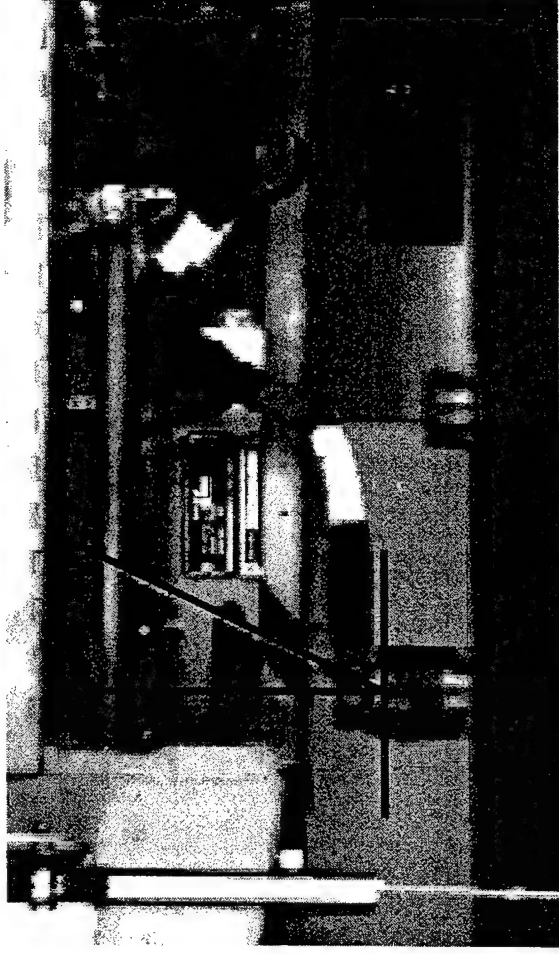
Hooks Open
Pulse

Bail Bar Strain
Gage

Measurement Definition

Pull Angle

Angle defined by the line perpendicular to the horizontal plane of the connector clockwise to the line made by the lanyard from the attach point on the connector to the bail bar using the film/video frame prior to the frame showing connector/receptacle separation.



Measurement Definition

Pull Rate

Static Test - Constant velocity preset as the speed of the MTS test machine.

Ejection Test - Velocity calculated using the aft Linear Velocity Transducer at the time indicated by electrical disconnect.

Measurement Definition

Pull Force

The peak force that was measured as the connector separated from the receptacle.

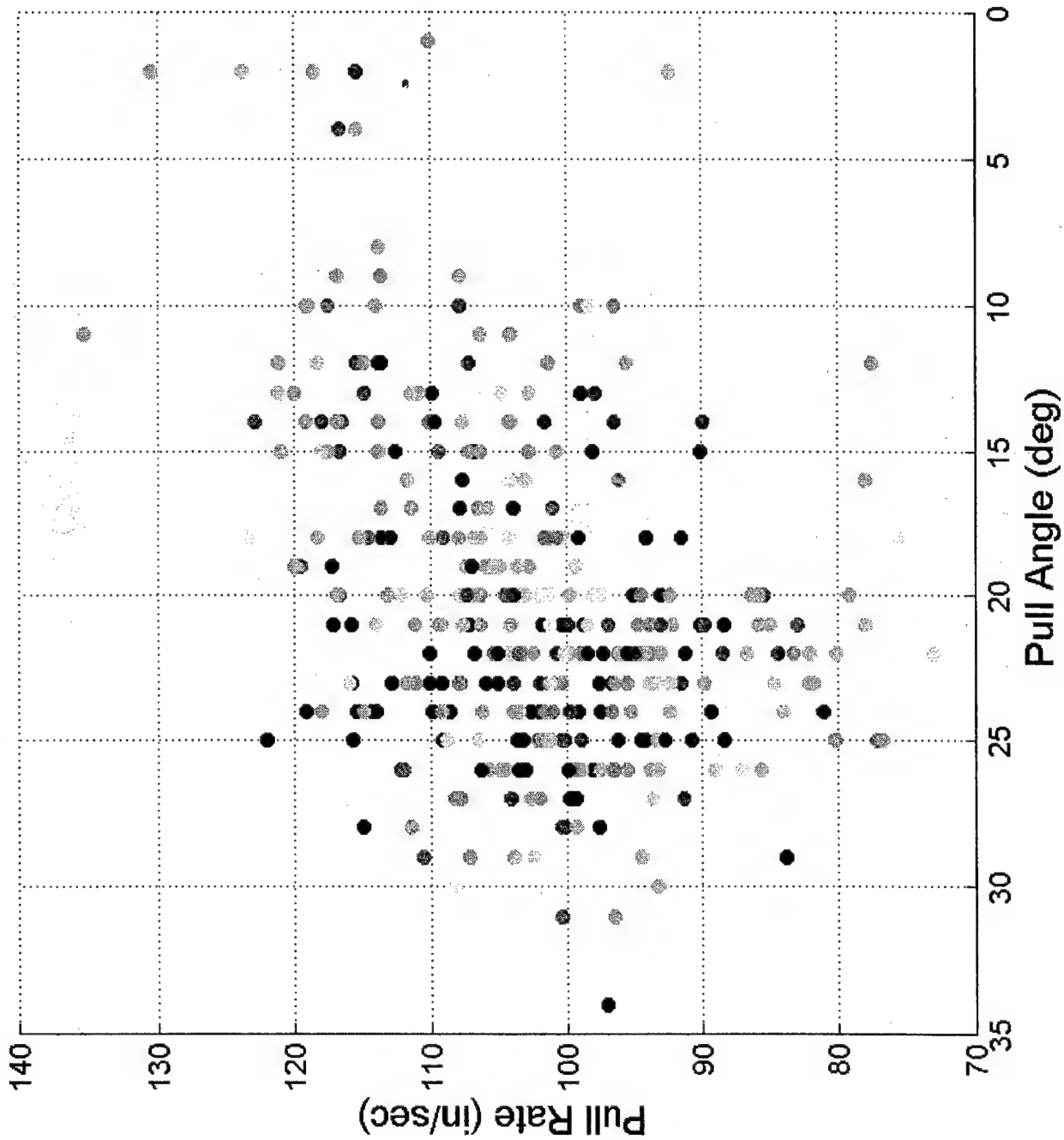
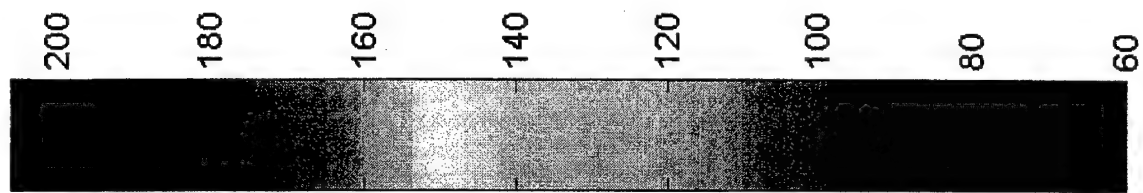
Static Test - Measured using a force transducer attached to the MTS machine. 1000 lbf range used.

Ejection Test - Measured bail bar deflection using bridge strain gage configuration. Bail bar calibrated to 300 lbf.

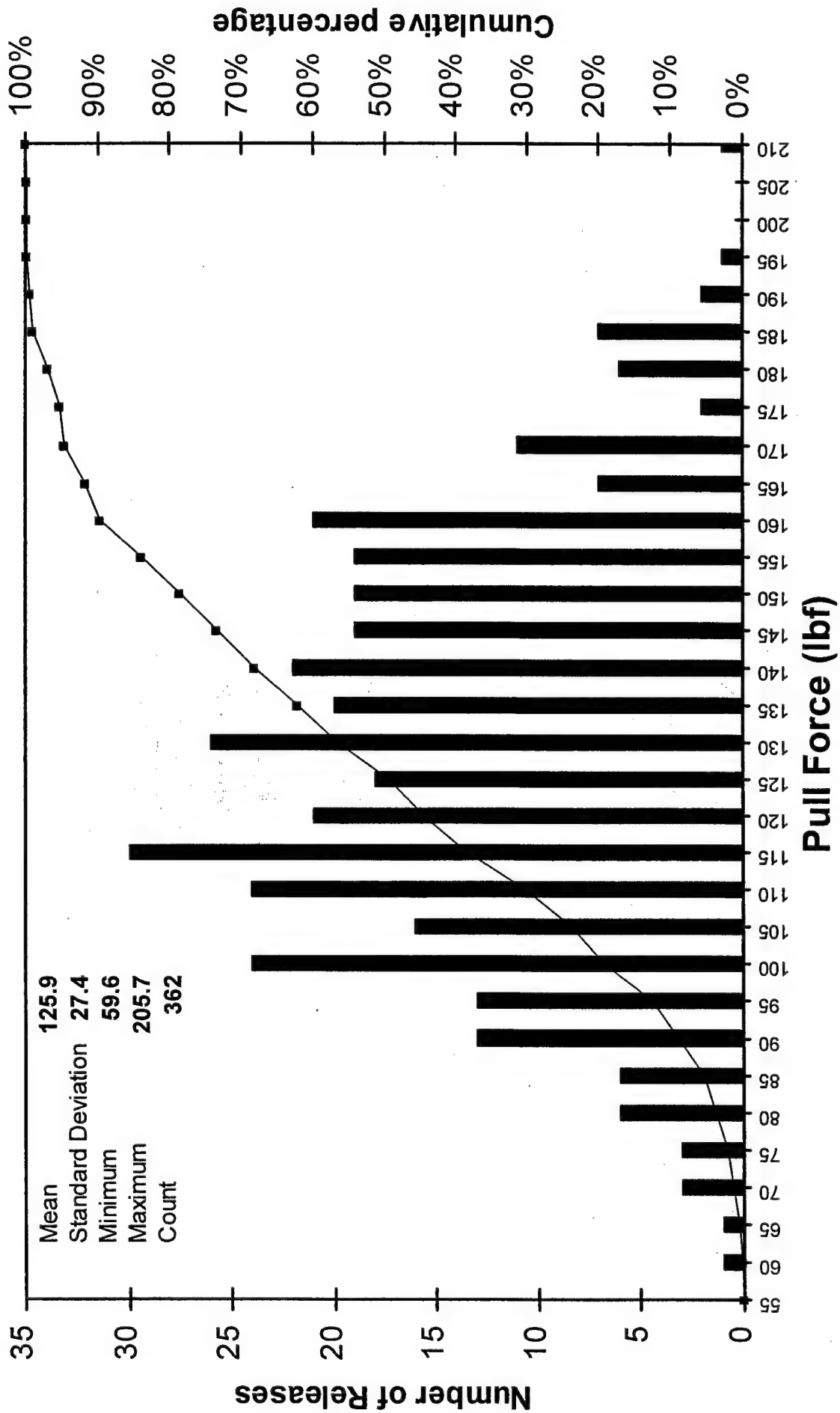
Other measurements were taken that related to safety and test conduct.

Forward Connector All Drops

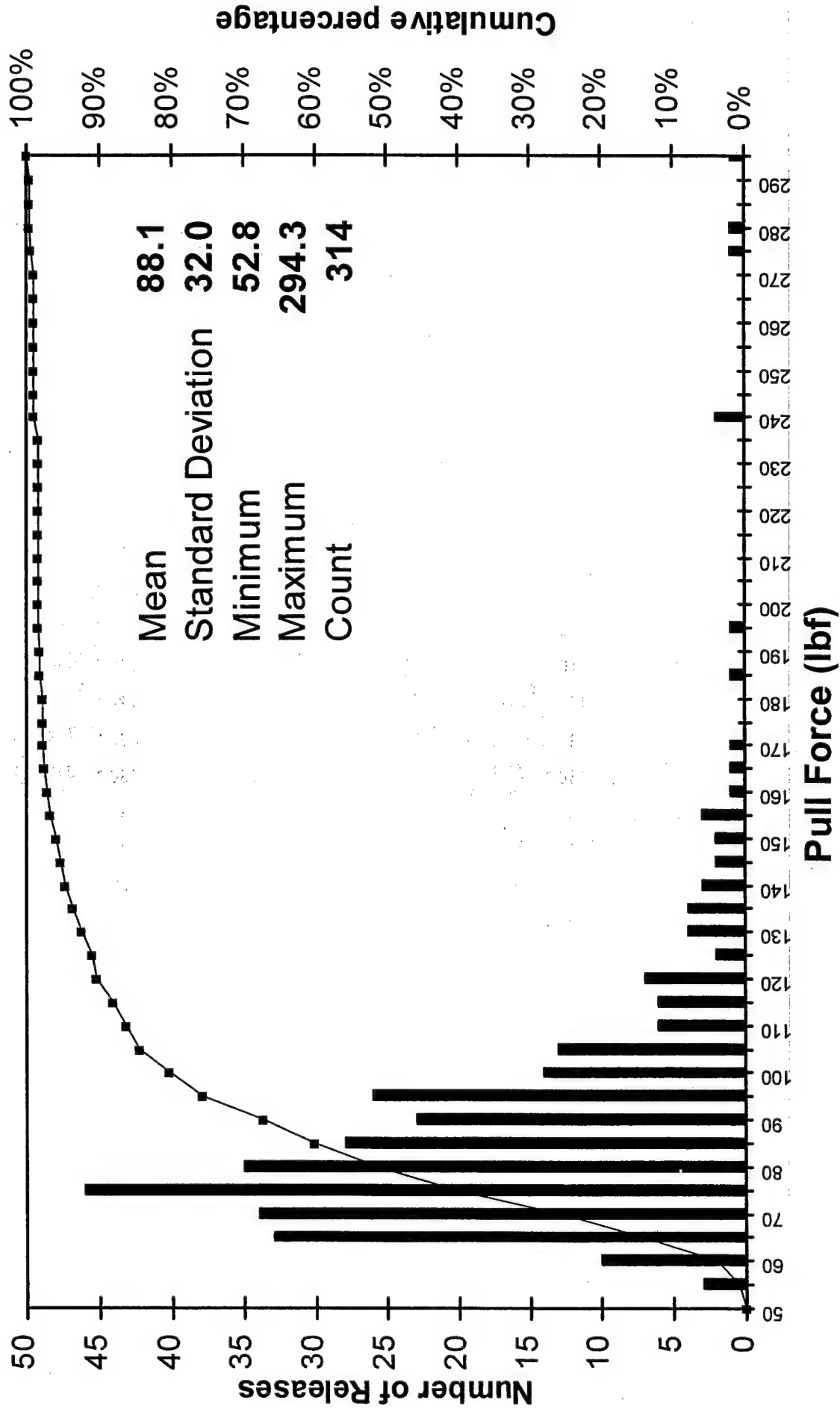
Pull Force (lbf)



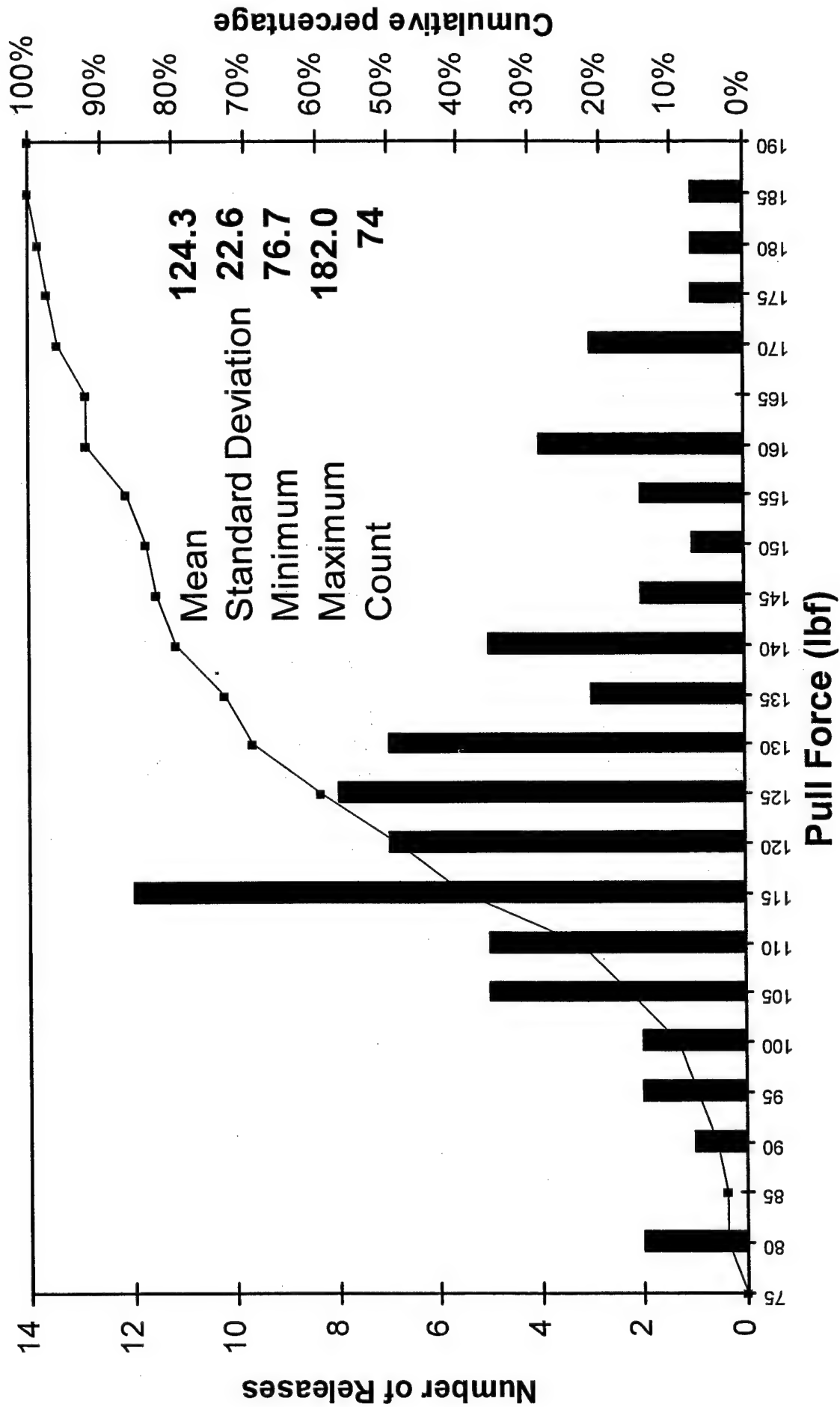
Histogram For Ejection Test (All Drops, Forward Receptacle)



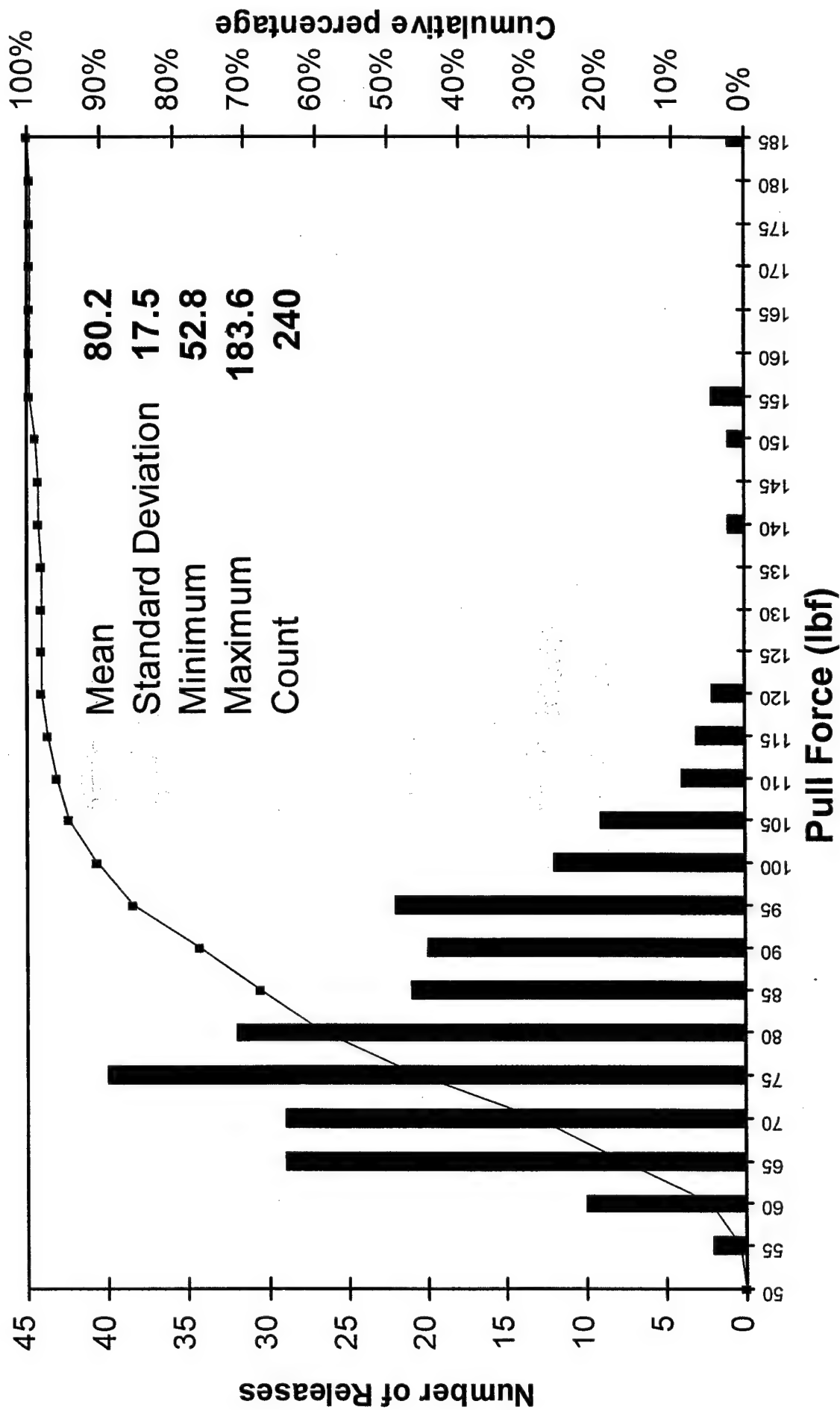
Histogram For Static Test (All Angles)



Histogram For Ejection Test **(Pull Angles $\leq 15^\circ$)**

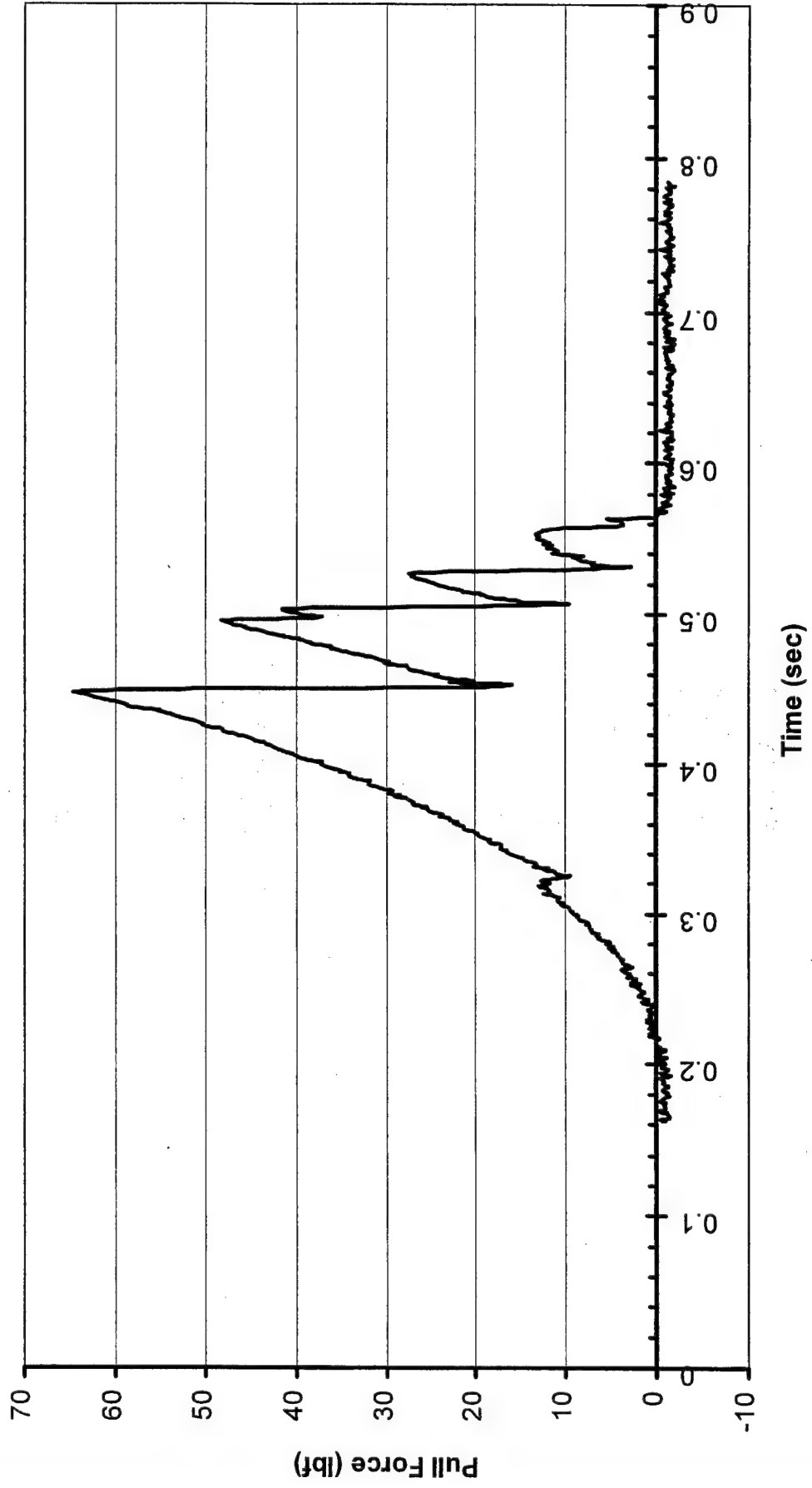


Histogram For Static Test (Pull Angles $\leq 15^\circ$)

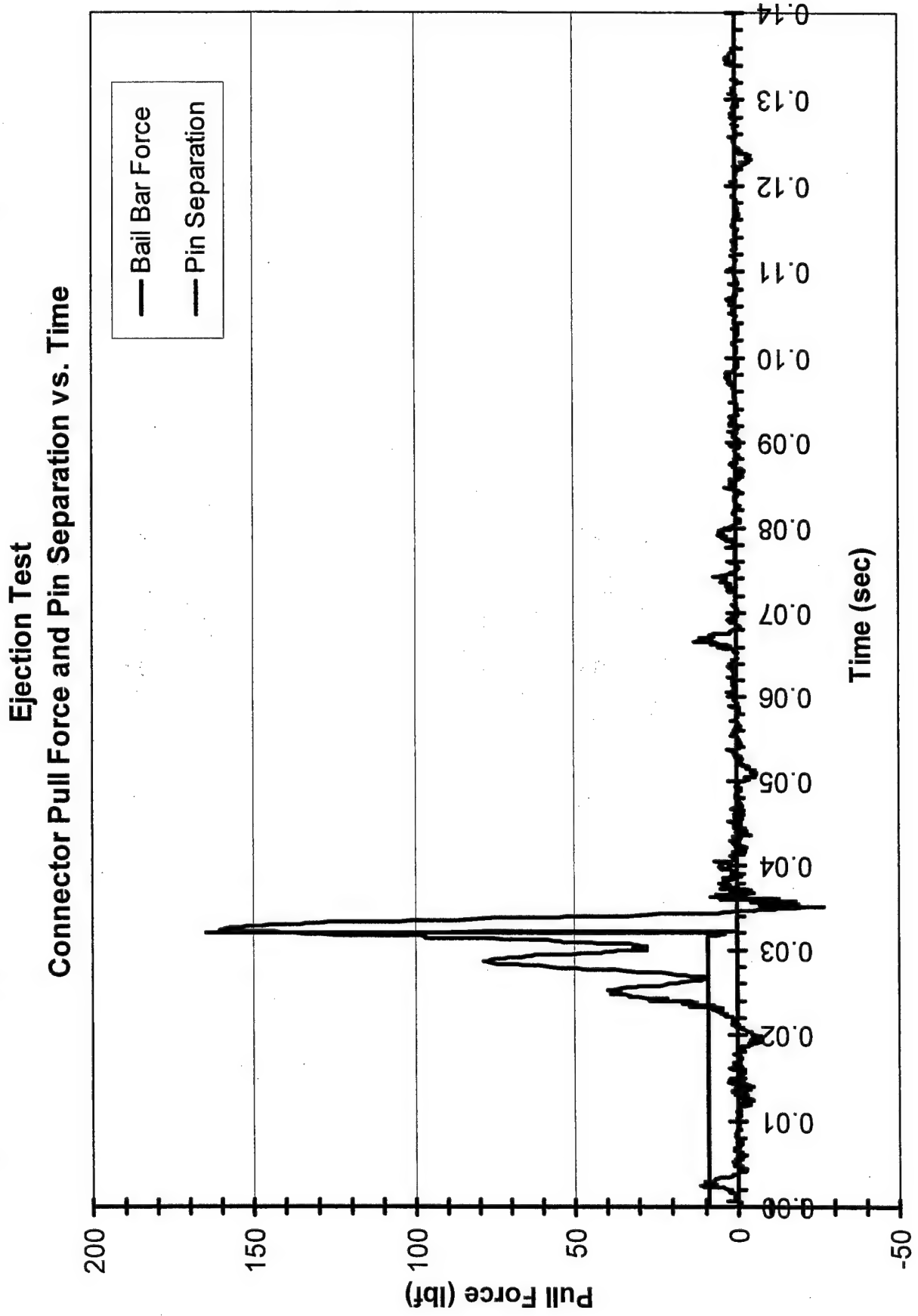


Example Pull Force vs. Time plots

Static Pull
Force Vs. Time



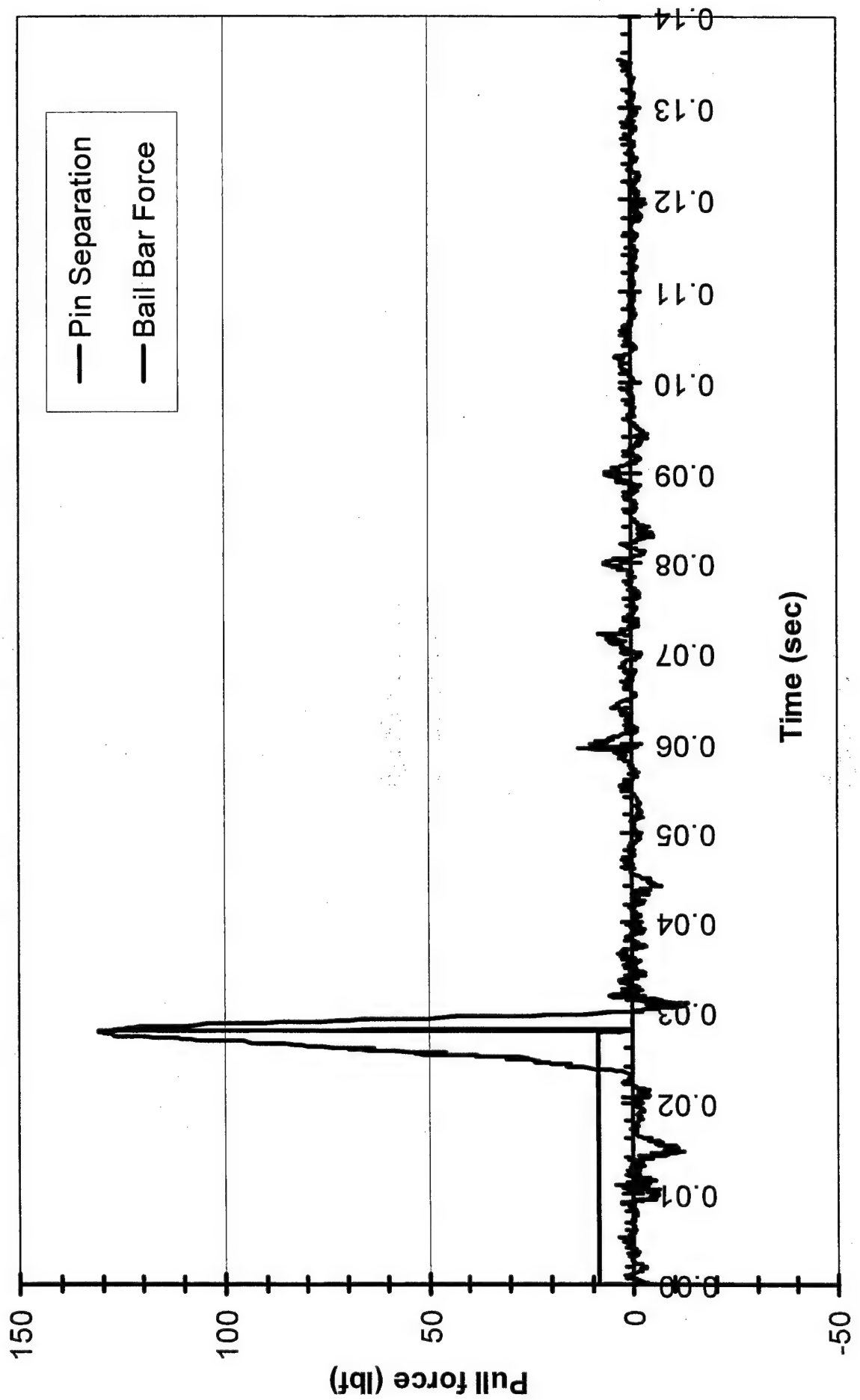
Example Pull Force vs. Time plots



Example Pull Force vs. Time plots

Ejection Test

Connector Pull Force and Pin Separation vs. Time



Composite Connector Damage Tolerance

- Teeth/Segments breakage
- Loading mishaps “Captain Crunch Syndrome”
- Impact resistance

Captive Carriage Flight Test

- 32.2 Hours flown with 4 different Cables
- Post-Release Configuration only
- 1 Dedicated Flight with Camera Coverage
- 12 “Piggyback” Flights
- Helped Improve Some Manufacturing Techniques

Post Certification Use

- Mk 83 JDAM Separation and DT-II Drops
 - only umbilical authorized
- Used on all F/A-18E/F 1760 Stores
- Looking forward to even lighter 1760 stores

Conclusions

- Separation prediction capabilities should use statistically significant empirical data vs DOD-C-38999/31 qualification pull force values.
- Longitudinal bail bar for lanyard connector release will result in uncontrolled pull angle and nonlinear pull force (skipping lanyard).
- DOD-C-38999/31 qualification requirements do not assure jam resistance/protection from excessive pull force at high pull angles or predict realistic ejected release pull rates.

Conclusions Cont.

- Composite Lanyard Release connectors provide damage tolerant performance.
- Composite Connectors are suitable in a lighting environment
- Kevlar lanyards are suitable for DOD-C-38999/31 Lanyard Release Connectors
- Properly structured ground test can provide useful data that is related to the in-flight environment.

Questions?

